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Technical Report

NATIONAL SEVERE STORMS FORECAST CENTER

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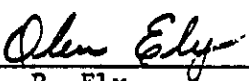
NATIONAL SEVERE STORMS FORECAST CENTER

Prepared For

DATA SYSTEMS LABORATORY
MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

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APPROVED:



O. P. Ely
Project Director

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INTRODUCTION

The National Severe Storms Forecast Center (NSSFCC) is a field organization within the National Weather Service. The NSSFCC is classified as a first-tier or first-echelon organization within what is basically a three-tier organization, as illustrated in Figure 1. The National Meteorological Center (NMC) is also a first-tier organization but is shown slightly elevated above the others because of the centralized/overall weather functions it performs.

The principal mission of the NSSFCC is to maintain a continuous watch of weather developments that are capable of producing severe local storms, including tornadoes, and to prepare and issue messages designated as either Weather Outlooks or Tornado or Severe Thunderstorm Watches for dissemination to the public and aviation services. In addition to its assigned responsibility at the national level, the NSSFCC is involved in a number of programs at the regional and local levels in areas around Kansas City, Missouri, where the center is located. Subsequent subsections and paragraphs describe the NSSFCC, its users, inputs, outputs, interfaces, capabilities, workload, problem areas, and future plans in more detail.

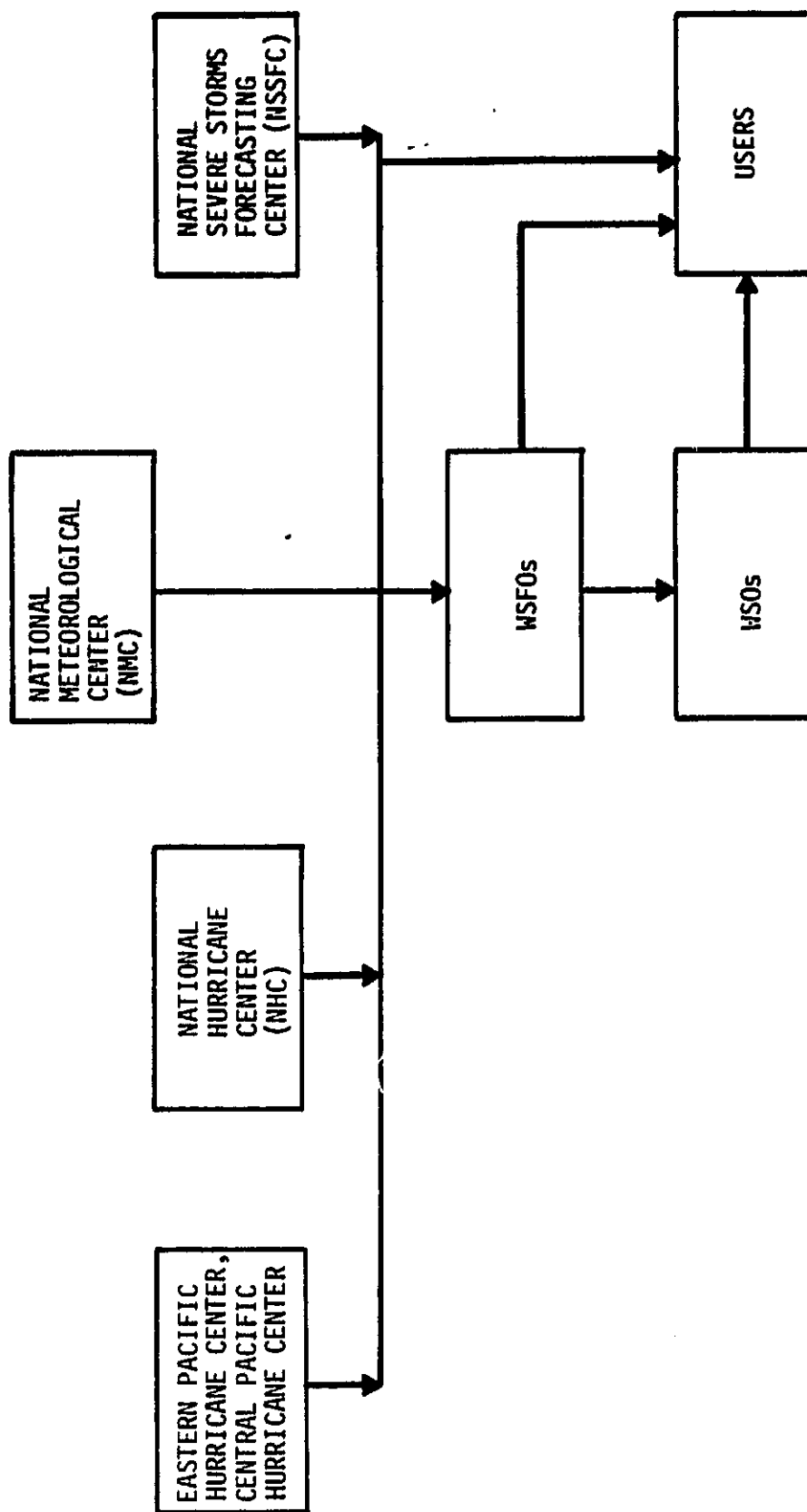


FIGURE 1. GENERAL NWS FORECAST ORGANIZATION STRUCTURE

1. NSSFC ORGANIZATIONAL ELEMENTS, PRODUCTS, AND USERS

The NSSFC organization is presented in Figure 1-1. Programs at the national level within the NSSFC are administered through four organizational elements as follows:

- Severe Local Storms Forecast Unit (SELS)
- Radar Analysis and Developmental Unit (RADU)
- National Public Service Unit (NPSU)
- Communications Center.

SELS has the responsibility for issuing severe thunderstorm and tornado watches for the contiguous 48 states. This unit maintains a continuous watch for thunderstorm activity and issues periodic weather outlooks (3 a.m., 10 a.m., and 2:30 p.m.) during the storm season from February through August. In addition, SELS also issues severe thunderstorm and tornado watches for specific areas and time periods from 1 to 6 hours in advance of projected storm activity and at other times when conditions appear favorable for severe weather. SELS transmits a graphic presentation of the storm forecast over the National Facsimile (NAFAX) circuit and issues narrative watch information via the 100-word/min teletype circuits.

RADU prepares an hourly composite picture from the radar reports received from more than 100 radar sites within the contiguous United States and southern Canada. This graphic picture of radar activity is transmitted 16 times daily over NAFAX and NAMFAX circuits. RADU personnel also keep the SELS forecasters briefed on significant storm development, and they serve in a quality control capacity by notifying regional offices of noted discrepancies in radar observations.

NPSU has a staff of five meteorologists who prepare weather information of national interest. Included in their products are the National Weather Summary (issued four times daily), the Selected Cities Weather Summary (issued twice daily), and the Travelers Forecasts (issued twice daily). Special forecast summaries for national holidays are also prepared by this unit. National dissemination of these NPSU products is

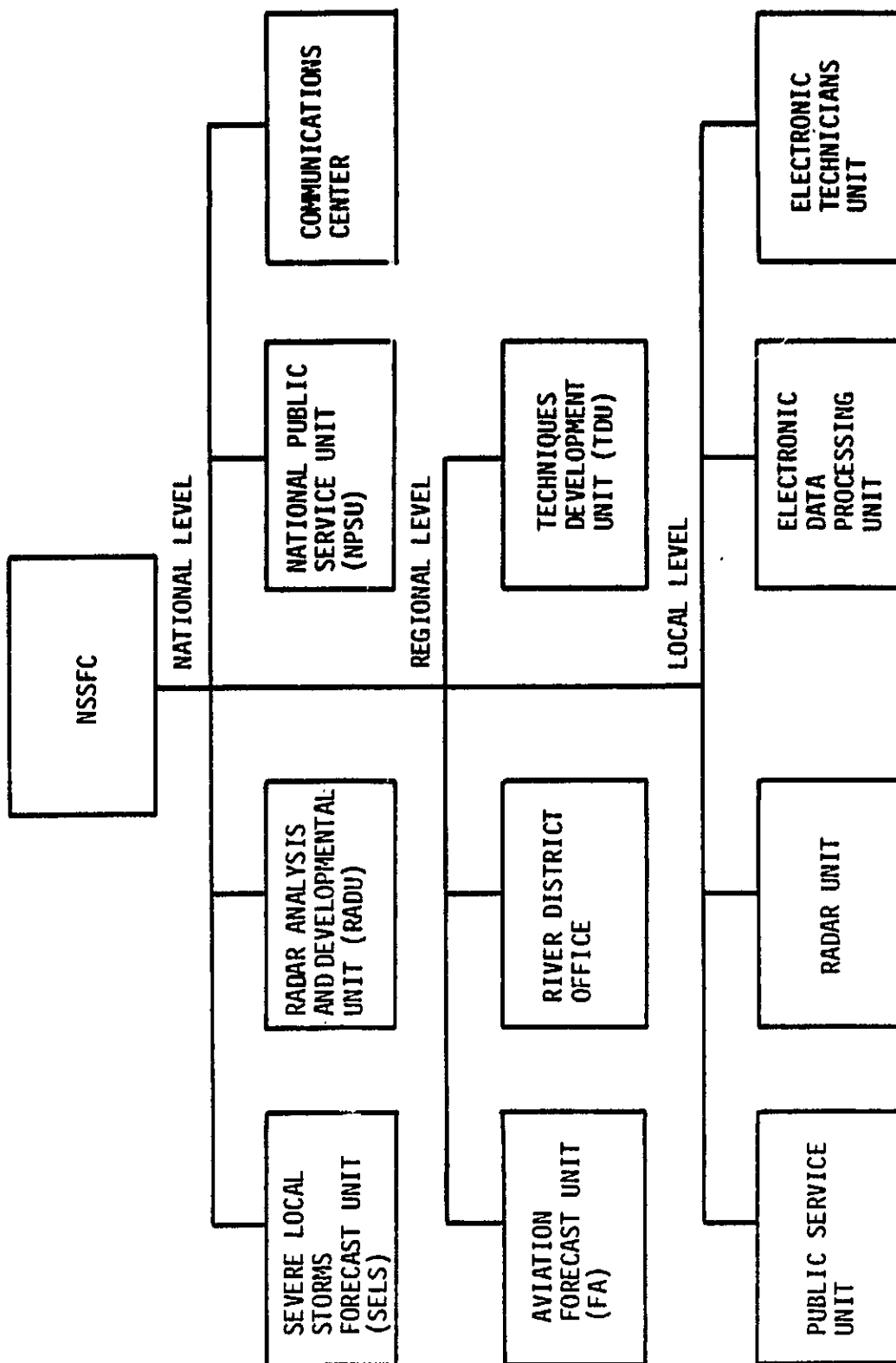


FIGURE 1-1. ORGANIZATIONAL STRUCTURE OF NSSFC

achieved through a KCRT link-up with the National Meteorological Computer Center, which in turn distributes information to users via Service C and the NOAA Weather Wire systems. The NPSU meteorologists also assist the local Public Service Unit by preparing VHF broadcast tapes of the National Weather Summary and the local forecast at selected times.

The Communications Center is the monitor station for the internal Weather Service, RAREP (Radar Reporting), and Warning Coordination System (RAWARC), which consists of approximately 250 stations transmitted over five circuits. Another terminus is the Technical Control Section (Communications Division) at Suitland, Maryland. Another function of the Communications Center is to monitor and control the Central Region overlay circuit of 10 stations. The task of this circuit is to supply weather warnings, radar summaries, zone and local forecasts, and other environmental data to state relay centers for entry onto state loops for the press, radio, and television. This unit relays information to the press and news media via the NOAA Weather Wire Service. In addition, the Communications Center edits and distributes forecasts and warnings issued by the NSSFC and enters 16 radar summary maps on the National Facsimile Circuit every 24 hours.

Regional level programs include the following:

- Aviation Forecast Unit (FA)
- River District Office
- Techniques Development Unit (TDU).

The FA unit issues aviation forecasts for the area covering Nebraska, Kansas, North and South Dakota, Colorado, and Wyoming based on route and terminal forecasts prepared by the six WSFOs representing these states. These forecasts, which are issued twice daily for periods up to 24 hours, include visibility, ceiling, precipitation, surface winds, freezing level and icing, turbulence, and other weather elements of concern to aviation. As necessary, FA issues In-Flight Advisories concerning potentially hazardous flying weather for broadcast through FAA facilities to aircraft in flight and directly to FAA and NWS briefing personnel. The unit also issues zone forecasts for the Kansas City and St. Joseph areas, as well as severe weather warnings for an area of responsibility encompassing 37 counties.

The River District Office is responsible for collection and distribution of regional hydrologic data from cooperative observers and 30 automatic gages, administration of the hydrologic network, and issuing preliminary crest stage forecasts using the Basin Headwater indices during times when the River Forecast Center is not manned. It also computes and administers the payroll for all paid observers and maintains station files for each station.

TDU is currently engaged in a program of organized research aimed at general improvement of decision-making procedures in prediction of severe storms, analysis of prediction errors, minimization of subjectivity in reaching a forecast decision, and identification of weather conditions leading to warning requirements. Objective prediction techniques that are available to the forecaster provide solutions that vary widely and produce errors that are typically difficult to identify and analyze. The primary task of the TDU is to apply scientific and systematic study to severe storm forecasting. To accomplish this function, the TDU group develops diagnostic procedures and programs that can be used by the forecaster to interpret and objectively apply information concerning storm structure and its environment. Personnel of the TDU have a physical insight into the dynamic and thermodynamic properties of the severe storm and what influences its development and movement, as well as having a knowledge of the procedures and thought processes used by the forecaster. They are experienced in the use of computers, development of diagnostic programs, and error analysis in numerical prediction models. There is a continuous interface between this group and the forecasters in order to understand problems of the latter, to provide new procedures for the solution of these problems, and to receive the forecaster's reactions to these procedures.

Local level units of NSSFC include the following:

- Public Service Unit
- Radar Unit
- Electronic Data Processing Unit
- Electronic Technicians Unit.

The Public Service Unit distributes most of the weather information that reaches the public. Its personnel prepare and disseminate severe weather statements, special weather statements, and river statements and disseminate severe thunderstorm, tornado, flash flood, and river flood warnings for an area covering 37 counties in northwest and west central Missouri and extreme east central Kansas. The major portion of this weather dissemination is by means of the NOAA Weather Wire, radio and television stations, and over two VHF Weather Service radio stations -- KEC-77 (St. Joseph) and KID-77 (Kansas City).

The Radar Unit operates a WSR-57 radar as an observation network station and is currently engaged in the test and evaluation of the D-RADEX program. Equipment for the D-RADEX system includes a NOVA 1200 mini-computer, a WBRR-68 Radar Remoting System, radar photographic devices, and a Video Integrator and Processor. The console of the WSR-57 radar is located within NSSFC, but the antenna is atop the old Federal Office Building (0.5 mi. to the northwest). The connecting link between the two major components is a microwave system.

The Electronic Data Processing Unit operates CDC 3100 and Varian 620/L computers. Central Region Headquarters and the Central Logistics Supply Center (CLSC) share the computer system, which performs selecting, sorting, and calculations necessary for prediction of severe weather, aviation weather, and other public forecasts such as snow, rain, and cold waves. The system is also used for research and investigation of severe local storms and other weather phenomena. During off hours, supply and inventory programs are handled for the NOAA CLSC group.

An Electronic Program Officer and five technicians at NSSFC comprise the largest staff of electronics technicians in the Central Region. This group maintains surface observation equipment at the Kansas City Municipal Airport, Kansas City International Airport, and Rosecrans Field (St. Joseph, Missouri). In addition, they maintain most of the hydrological equipment within the area of responsibility of the Kansas City River District. Other equipment maintained by this staff includes

the WSR-57 radar and its associated microwave link, the Video Integrator and Processor, WBRR Radar Remoting System, NOVA 1200 minicomputer, facsimile transmitters, teletype, and the two VHF radio stations.

2. DATA INPUTS

The NSSFC serves national, regional, and local functions in relation to severe weather forecasts. In addition, it serves a number of research functions. Data inputs discussed herein relate only to those inputs that apply to national severe storm forecasting.

The NSSFC has access to weather data from all observing stations in the U.S., from satellites, and from acquisition points near the U.S. which receive data that affect continental U.S. weather. The information is received via 100-word/min teletype circuits, various high-speed communication lines, and facsimile circuits to other data collection and processing centers. In addition, NSSFC has immediate access to high-quality satellite data from the National Environmental Satellite Service Field Office, which is located on the same floor of the Federal Building in Kansas City. (For more details on the communications capabilities of the NSSFC, see Section 4).

The data available to NSSFC forecasters (not in the order of importance) are:

- Surface weather observations (usually referred to as Aviation Weather Observations) from approximately 1,000 land stations and numerous ships in the ocean and Great Lakes areas at periodic intervals (6-hour intervals for synoptic observations and hourly intervals for basic observations)
 - ▲ Amount of Sky Cover
 - ▲ Types of Clouds
 - ▲ Cloud Height
 - ▲ Wind
 - ▲ Visibility
 - ▲ Weather
 - ▲ Temperature
 - ▲ Barometric Pressure
 - ▲ Altimeter Settings for Aircraft
- Upper-air observations from more than 100 rawinsonde, pilot balloon, and rocket sounding stations provide vertical and horizontal distribution of pressure, temperature, water vapor, and wind:

- ▲ Pilot balloons provide low-level, upper-atmospheric wind information below 20,000 ft.
- ▲ Rawinsondes provide three-dimensional information on pressure, temperature, moisture, and winds aloft to altitudes averaging slightly more than 100,000 ft.
- Radar observations from 94 NWS weather radars (52 network sites and 42 local warning radars) and selected FAA air traffic control radars in the western U.S. network sites report hourly via the RAWARC network, and facsimile pictures of the network and FAA radar scopes may be called up and viewed in near real time by the Radar Analysis and Development Unit (RADU) on demand. Local-warning radars report on an as-required basis:
 - ▲ Radar observations provide areal coverage, height, intensity, and movement of precipitation patterns.
- Satellite observations from GOES-1 and SMS-1 are received periodically. Cloud-cover photographic information and infrared photographs are received alternately at 0.5-hour intervals during the day-light hours, and infrared photographs are used exclusively at night.
- FAA pilot reports of severe weather
- Guidance information from the National Meteorological Center (NMC) in the form of analyses and forecasts that are provided via teletype and facsimile.

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3. NSSFC OPERATIONS

The SELS unit of NSSFC has responsibility for national severe storm forecasting. The operations of this group, in conjunction with the Radar Analysis and Development Unit and the Communications Center, are discussed in terms of their interface to other weather service elements and the users.

SELS has access to all the input data discussed in Section 2, either in its processed or unprocessed form. The starting point for severe storm forecasts is the guidance data provided by the NMC. The data are provided in the form of computer-generated weather maps and narrative summaries transmitted four times daily via facsimile and teletype circuits to the NSSFC, WSFOs, and Weather Service Offices (WSOs). These forecasts from the NMC are generated using highly complex computer models that are capable of predictions over large geographic areas. Local weather within these areas requires more detailed analysis by the NSSFC/SELS forecasters, who analyze the guidance data in conjunction with the hourly surface observations and synoptic data, the RADU-provided Radar Summary Charts (the RADU produces hourly radar summary charts based on data received from the network and FAA radar sites and any as-needed reports received from local radars), satellite data, upper air soundings, and FAA pilot reports. In addition, SELS has access to all observations stations on an as-needed basis during times of potentially severe weather, and they can call up facsimile charts of radar screen presentations at any of the network or FAA radar sites.

The surface observation and synoptic data and the upper air sounding data that come into the NSSFC are available either as teletype printouts or in the form of computer compatible data via a 2,400-baud line to the FAA switching center data base. The data that are received via the 2,400-baud line are selected and sorted, and calculations necessary for prediction of severe weather are made. Figure 3-1 presents a portion of a surface chart that is a composite of the output products produced from this data. Outputs include temperature, dew point, wind speed and direction, barometric pressure, visibility, and changes in barometric pressure since the last report.

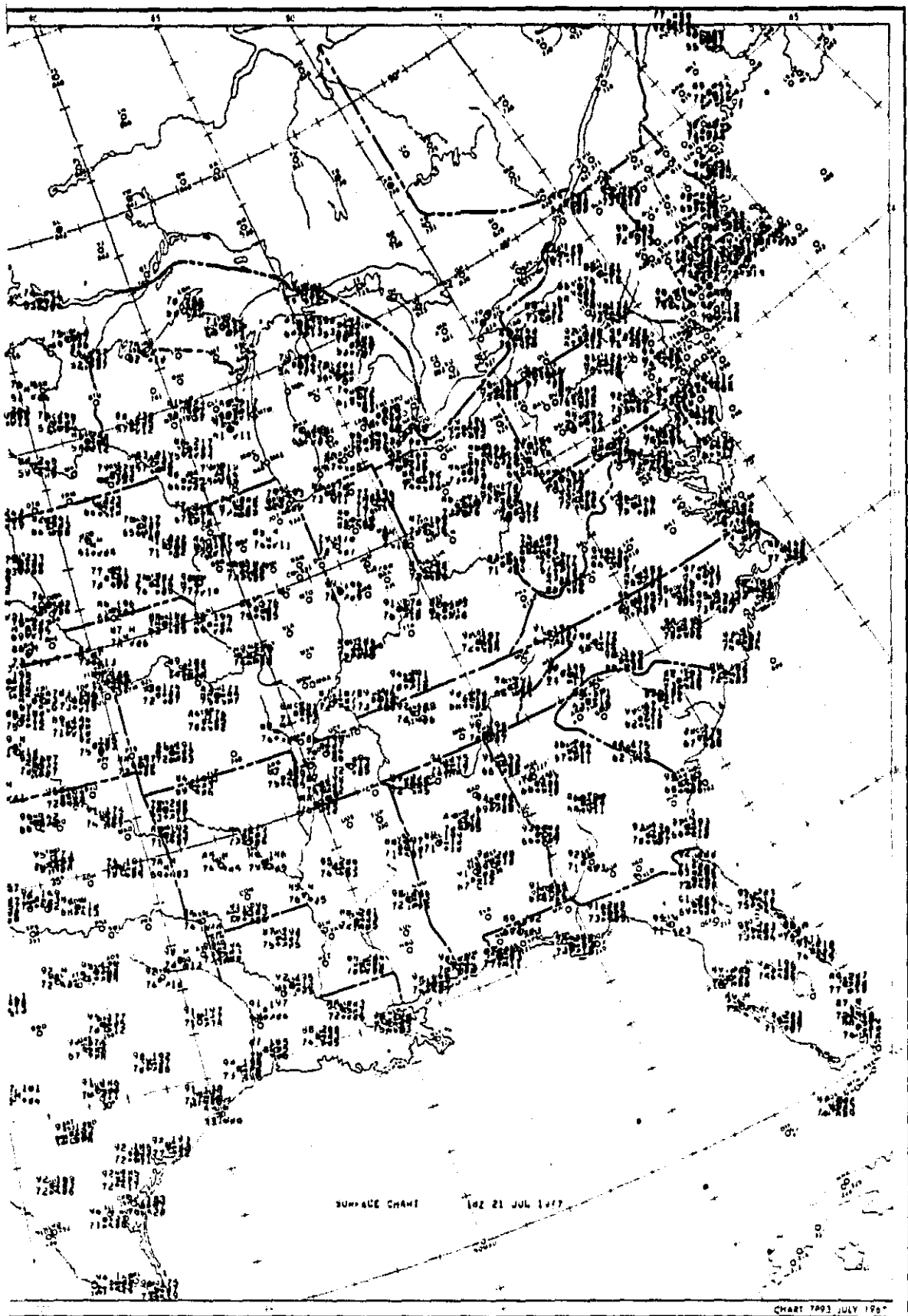
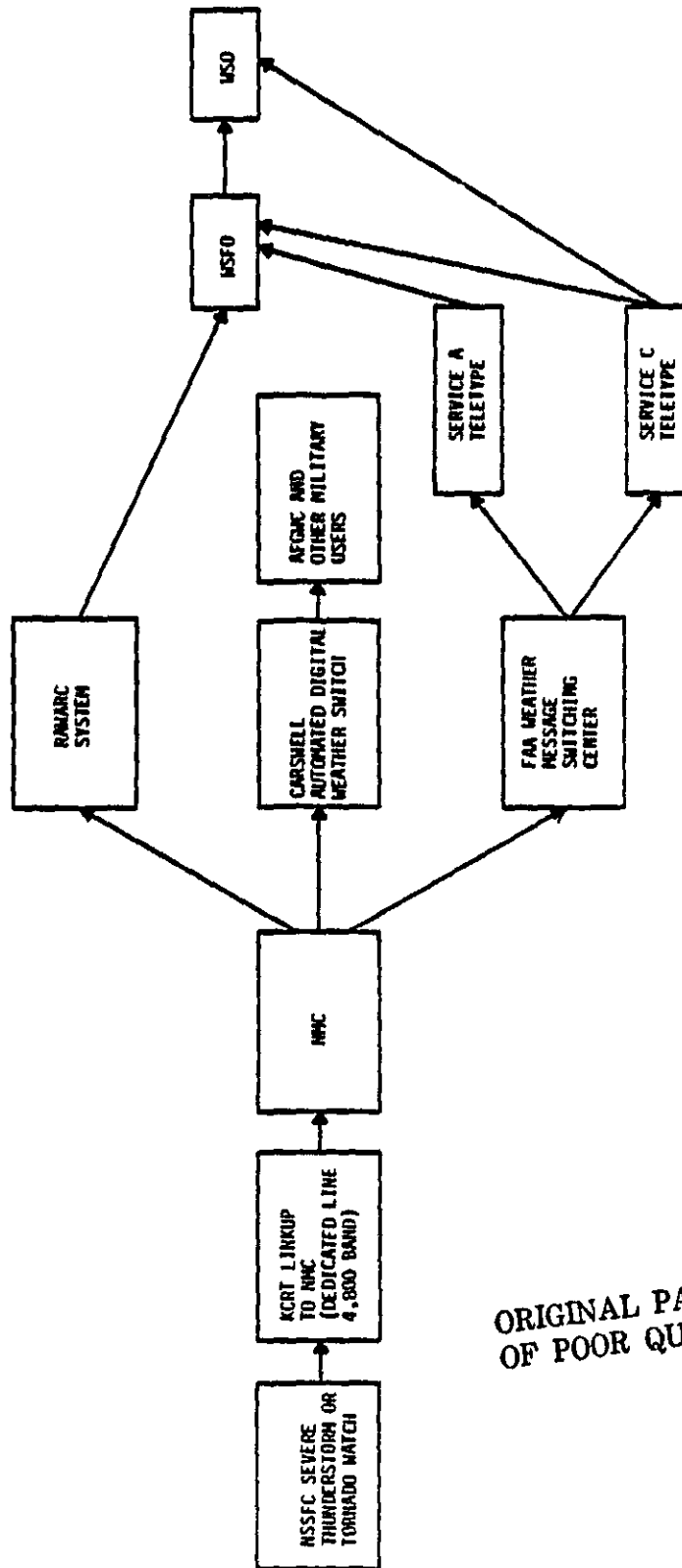


FIGURE 3-1. NSSFC COMPUTER-GENERATED SURFACE CHART

All data are continually assimilated and analyzed manually by the SELS forecasters to develop forecasts for areas where severe local storms are likely to occur. Three times daily, SELS issues periodic weather outlooks that identify areas where severe storms are likely to occur in the coming 24-hour, 18-hour, and 12-hour periods. These forecasts may cover large geographic areas that involve one or more states. The data are disseminated to the general public via the news media and to aviation users via NWS/FAA networks.

NSSFC maintains close watch over the areas where storm activity is forecast, and when data indicate that conditions are favorable for a severe storm or a tornado, SELS issues the appropriate watch (severe thunderstorms, tornado, or both). The information flow within the weather service and the FAA network for a watch is presented in Figure 3-2. Local WSOs issue warnings when severe thunderstorms or tornadoes are spotted within the watch area. (In practice, warnings may be issued without a watch when conditions warrant). The flow of warning information within the NWS/FAA network is presented in Figure 3-3. The flow of warning/watch information to the general public is presented in Figure 3-4 and the flow to air traffic users is presented in Figure 3-5.

The RADU receives and analyzes data via the RAWARC teletypewriter hourly (about 35 min past the hour) in RAREP (Radar Report) code. More frequent observations are taken and transmitted on RAWARC in severe weather situations. In addition, each ARTCC Radar Unit prepares a narrative summary of its hourly composite and transmits the summary on RAWARC. Routine military radar weather observations are also received from the Carswell Automated Digital Weather Switch (CADWS) through the FAA Weather Message Switching Center. These reports are used by the RADU to produce hourly composite pictures, which are plotted manually. These graphic pictures of radar activity are transmitted over NAFAX and NAMFAX circuits 16 times daily. The data flow to and from RADU is presented in Figure 3-6. This group also keeps the SELS group briefed on significant storm developments.



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FIGURE 3-2. DISSEMINATION OF SEVERE THUNDERSTORM OR TORNADO WATCH WITHIN NWS, FAA, AND DoD

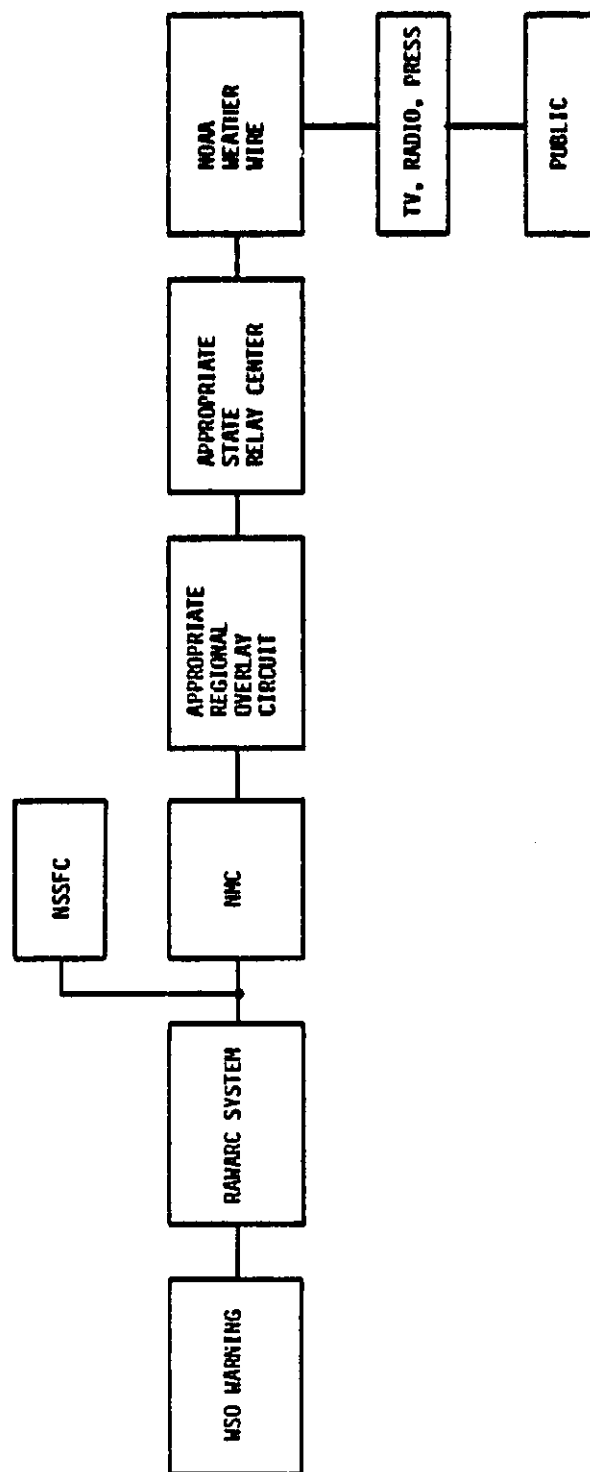


FIGURE 3-3. DISSEMINATION OF SEVERE WEATHER WARNING WITHIN NWS

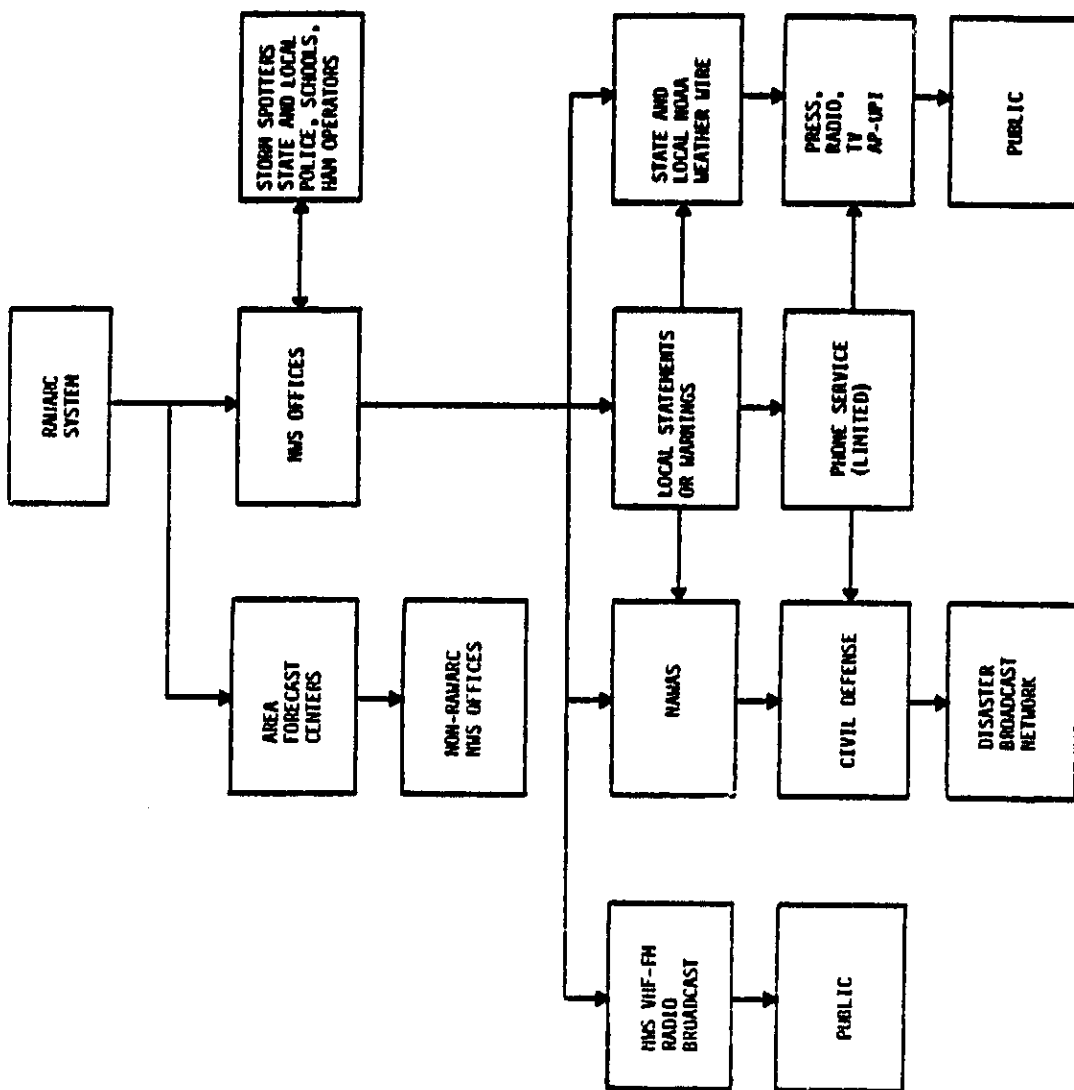


FIGURE 3-4. DISTRIBUTION OF COMBINED SEVERE WEATHER WATCH AND WARNING BULLETINS TO USERS

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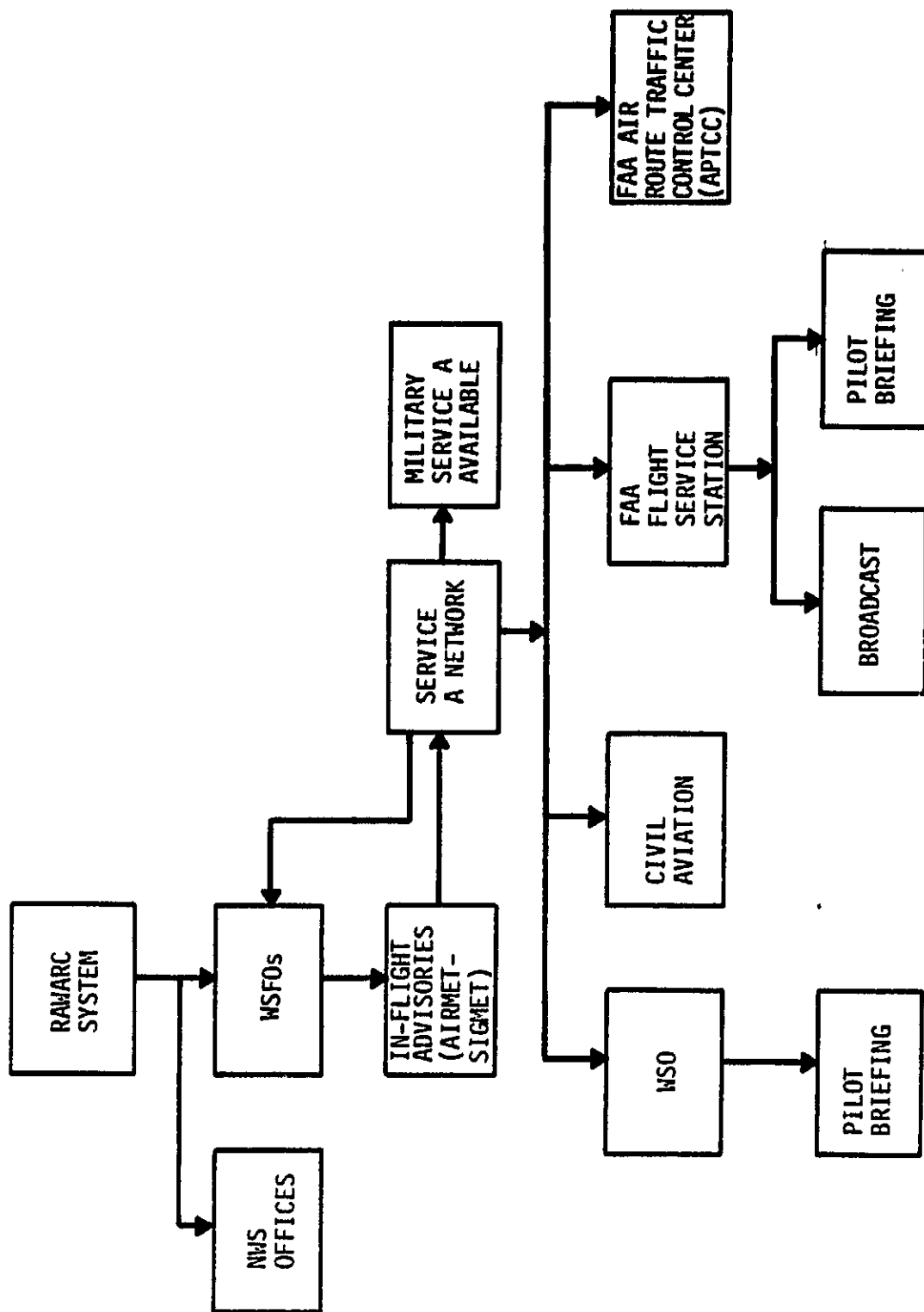


FIGURE 3-5. DISTRIBUTION OF AVIATION SEVERE WEATHER WATCH BULLETINS (AIRMET AND SIGMET) FOR AVIATION USERS

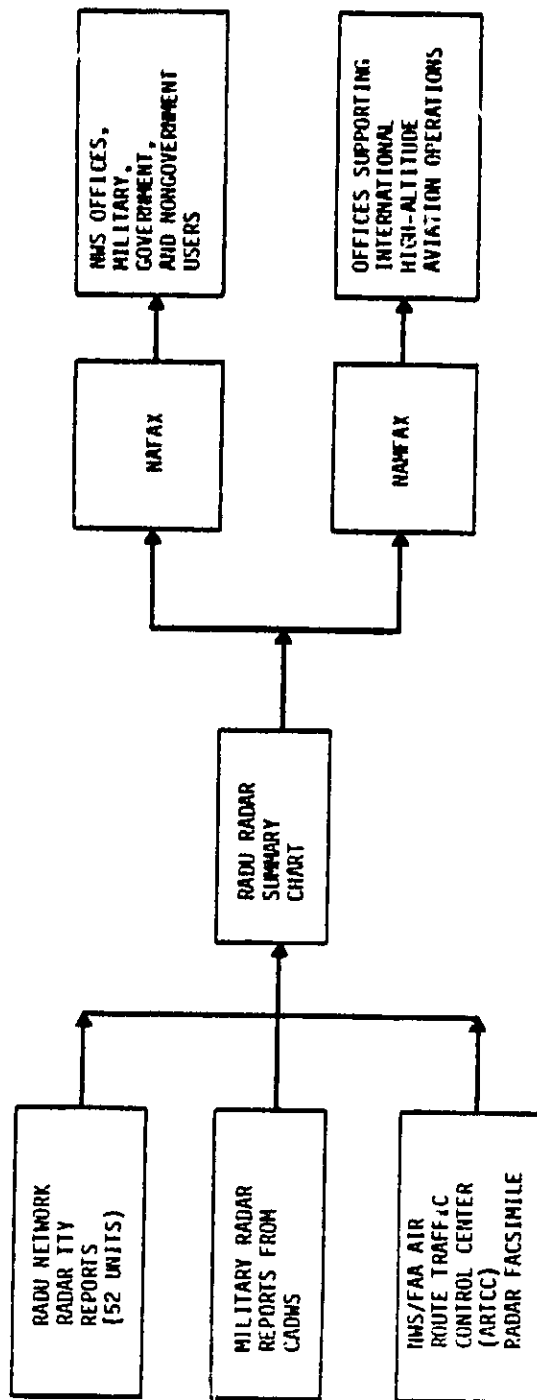


FIGURE 3-6. DATA FLOW FOR RADAR SUMMARY REPORTS WITHIN RADU

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The Communications Center monitors the RAWARC network, monitors and controls the Central Region Overlay Circuit, and edits and distributes forecasts and warnings issued by the NSSFC. It also enters 16 radar summary maps on the National Facsimile Circuit every 24 hours.

4. DATA HANDLING CAPABILITIES

Data handling capabilities for the NSSFC include all communications into and out of the NSSFC and the processing necessary to produce and display the output products for dissemination via the NWS, FAA, and DoD networks. All data elements described exist within the NSSFC located in Kansas City, Missouri, and are used for National Severe Storm forecasting.

4.1 DATA PROCESSING HARDWARE ELEMENTS

The principal electronic data processing hardware elements within the NSSFC are:

- 1 CDC 3100 computer with 16K words (24 bits)
- 4 CDC 607 magnetic tape drives
- 1 CDC 501 line printer
- 1 Varian 620/L computer
- 2 Varian tape drives (CDC 607 compatible)
- 1 Eclipse S/230 computer with 64K words (16 bits)
- 1 Diablo 1620 line printer/terminal
- 1 electrostatic plotter.

The above equipment is configured as illustrated in Figure 4-1, with each computer operating in a stand-alone mode with respect to the other computers.

4.2 DATA PROCESSING SOFTWARE ELEMENTS

The data processing software elements are listed in terms of the functions they perform in lieu of listing specific elements. All operating system software used by the computers are commercially available from the vendors. For example, the Eclipse S/230 computer uses Data General's AOS operating system with multiple partitions, which is Data General's most sophisticated operating system. The Varian 620/L uses Varian's Basic Executive Scheduling Timekeeper (BEST) and the CDC 3100 uses the Tape SCOPE Operating System. The data within the NSSFC are handled using standard file management software for the computers in use.

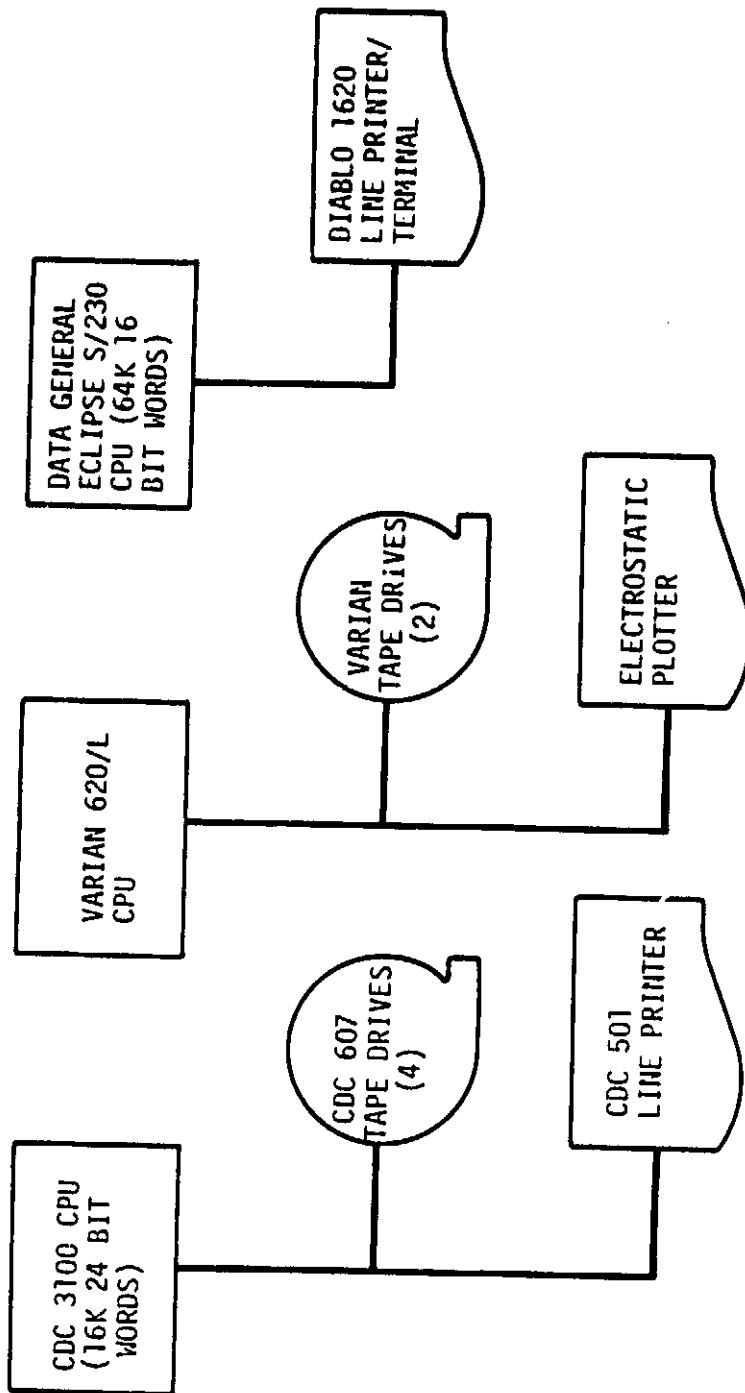


FIGURE 4-1. GENERAL CONFIGURATION OF NSSFC DATA PROCESSING HARDWARE ELEMENTS

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Software functions performed include:

- Communications Software
 - ▲ Varian 620/L to FAA Communication Center
 - ▲ Varian 620/L to NMC 360/40
- Tape Formatting Routines
 - ▲ Operational data
 - ▲ Archival data
- Plotting Routines
 - ▲ Surface observation data
 - ▲ NMC data via the 360/40
- Statistical Data
 - ▲ Operations
 - ▲ Historical weather data
- Administrative Support
- R&D, Experimental, and Test Routines including Operations in Conjunction with the NWS IBM 370/195.

4.3 COMMUNICATIONS ELEMENTS

The NSSFC communications capabilities support national, regional, state, and local operations. Those communications elements that are used to support national severe storm forecasting operations are:

- One 2,400-baud Line to the FAA Communications Center
- One 4,800-baud Line to the NMC IBM 360/40
- One 4,800-baud KCRT Line to the NMC
- NAFAX Facsimile Connection*
- FOFAX Facsimile Connection*
- Service C Teletype Connection*
- Service A Teletype Connection*
- RAWARC Teletype Connection*

The configuration of the high-speed data lines within the NSSFC is illustrated in Figure 4-2.

*For a discussion of the NWS/FAA communication network services, refer to report entitled: Survey: Federal Aviation Administration National Communication Center.

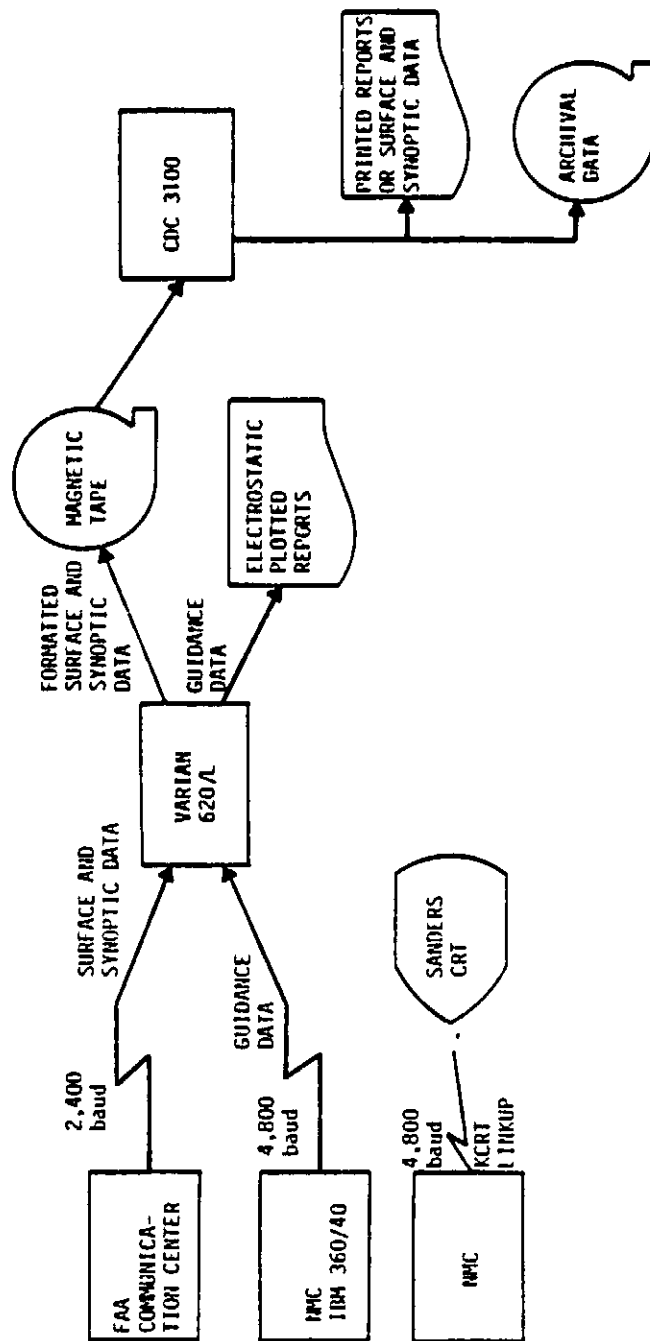


FIGURE 4-2. TELECOMMUNICATIONS CONFIGURATION WITHIN NSSFC
DATA PROCESSING FACILITIES

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4.4 NSSFC DATA HANDLING SYSTEM UTILIZATION AND WORKLOAD

The Varian 620/L computer in the NSSFC serves as the communications computer for interfacing to the FAA Switching Center Data Base and for interfacing to the NWS IBM 370/195 via the IBM 360/40. The system services scheduled and unscheduled communications for the FAA Switching Center and the NMC. Surface and synoptic data received via the 2,400-baud linkup to the FAA Switching Center are formatted onto tape for use by the CDC-3100. Guidance data received via the 4,800-baud link to the NMC are plotted on the electrostatic plotter.

The CDC-3100 computer is the primary production computer within the NSSFC. This computer selects, sorts, edits, and plots surface and upper air observation data and performs routine computations for use by the forecasters in their severe storm predictions. The primary inputs to this machine are scheduled inputs that have been received by the Varian 620 and recorded on tape for input to the 3100. The workload is thus very heavy during these production runs and is less than full capacity during interim periods unless storm activity is ongoing. The NSSFC uses these times to run their nonproduction, low priority jobs. The 3100 is not used for producing computer modeled forecasts since the models that would be involved would exceed the capacity of this machine. All computer generated forecasts are produced by the NMC IBM 370/195. These forecasts provide guidance to the NSSFC forecasters but are not yet capable of predicting and locating severe storms to the degree of accuracy necessary for protection of life and property.

The Data General Eclipse S/230 is a new computer that has been recently received by the NSSFC. The system is presently used for R&D functions by the Techniques Development Unit. It will eventually be used in conjunction with the NWS Automatic Field Operations Services (AFOS) system, which is discussed in a separate report.

In addition to the above computers, the NSSFC has a NOVA 1200 computer that is used within the NWS's D-RADEX system, which is an experimental system used at selected NWS sites to study the feasibility of obtaining automated radar data in a format that permits it to be integrated with the other types of observation using computer-generated models. The NOVA 1200 is dedicated to this activity.

5. FUTURE PLANS

The National Weather Service is in the process of evaluating and implementing a number of new systems, techniques, and computerized models that will significantly affect operations throughout the organization, including the NSSFC. Other reports address these plans in more detail; thus, this report should not be considered as complete with respect to these plans. Of equal importance, the NWS is actively pursuing a number of alternative solutions to some of its problems (see Section 6), and the various options being investigated are still in various stages of test and evaluation. In view of this ongoing work, the final direction that future plans will take in a number of areas is still not firm.

The most significant planned change to NSSFC facilities and operations is the implementation of the AFOS system. When implemented within the NSSFC in the 1978-1979 timeframe, this system will completely replace the existing method of data handling. In the first place, the system will replace the existing teletype and facsimile circuits that come into the NSSFC. It appears that this system will eliminate the NSSFC's dependence on the FAA Switching Center; however, this was not confirmed. Simultaneously, all paper products (teletype printouts, facsimiles, etc.) will be replaced with cathode ray tube (CRT) presentations (alphanumeric and graphic presentations that include detailed maps) that may be called up on demand. Presentation will be enhanced through the use of offset and zoom capabilities. Thus, the capability exists to use the full display screen to display an area where severe local storms are occurring to improve and speed up the forecast. Also, up to three analysis and forecast charts can be recalled on a single screen without disturbing the original image. This feature enables forecasters to accurately track storm and other weather patterns and to rapidly access changes that are taking place.

The CDC 3100 computer, which is the present production machine within the NSSFC will be replaced by the two Data General Eclipse S/230 machines that accompany the AFOS. The need to handcarry tapes between the communications computer and the production computer will be eliminated. Messages generated at the NSSFC for distribution to the NMC and field centers will be composed on the AFOS keyboard, and the time between initiation and distribution will be reduced from approximately 5 to 8 min currently to approximately 2 to 3 min. In addition to the aforementioned capabilities, the AFOS system will maintain the NSSFC data base and the role of the processor will continue to increase as improvements are made in data handling, modeling, and automated forecasting.

Other areas in which improvement in NSSFC operations are planned are automation of radar data processing, automation of satellite data input and processing, and development of more sophisticated techniques for automatically combining surface, upper air, radar, and satellite data. However, plans in these areas are still in various stages of evaluation and formulation. For more details on the problems associated with these plans, refer to Section 6.

6. NSSFC PROBLEM AREAS

This subsection lists and briefly describes specific problem areas that have been identified with respect to NSSFC operations. An attempt is made to describe the nature of some of the more complex issues and to identify efforts that are being made to improve some of the key problem areas.

Problems identified, not necessarily in the order of importance, are as follows:

- Prediction of a severe storm is still an inexact science. Only 50% of the severe storm watches issued by NSSFC verify, and only 33% of the tornadoes that are reported occur in watch areas. While large-scale weather forecast prediction accuracy has improved significantly over the past 10 to 15 years, Edwin Fawcett (Ref. 6-1) of the NMC concludes that very little progress has been made in forecasting precipitation and other small-scale elements.
- Weather forecasters still have to depend on personal skill and experience to interpret numerical guidance, and as a result, small-scale weather forecasting is highly subjective. NSSFC forecasters depend entirely on visual inspection for merging radar, satellite, and sounding data.
- Models for forecasting and efficiently displaying severe storm data do not exist. Radar data are still hand-plotted, and a significant amount of work is still required to develop experimental systems for automating these processes. For example, the D-RADEX program for automating local radar readings experiences many problems, some of which can be attributed to ground clutter and other propagation anomalies. The resulting data are unusable unless these problems are overcome.
- Sufficient input data are not available and the capability (hardware and data models) to adequately use more data is limited.
- Frequently, critical data on severe storm activity, particularly tornadoes, are received too late to be effective.

- Forecasters do not regularly receive feedback information regarding the accuracy of their forecasts.

The following paragraphs discuss certain of the above problems in more detail and identify one program that is directed toward overcoming some of the major difficulties.

A major problem with the prediction of a severe storm is insufficient spatial resolution of data needed to locate and identify the areas where conditions are favorable for storm formation. This is the result of the relatively sparse network of observing sites, particularly upper air sounding sites, and the relatively small scale of the thunderstorm activities that take place. As an example, Pearson (Ref. 6-2) points out that the data received from rawinsondes worldwide are the basis of all scientific forecasting as we know it. Yet, typical spacings between rawinsonde soundings is 250 mi. and soundings are taken only twice daily. This spacing for soundings works well for large-scale weather observations but is likely to be unrepresentative of local weather, such as severe storm conditions and strong inversion layers. In a recent discussion with TBE personnel performing this survey, Pearson stated that a sample interval of 100 km is needed for NSSFC to adequately perform their job.

Assuming that more data were available, two other major problems still exist. First, numerical models capable of accurately predicting locally severe storms do not currently exist. Richard Anthes (Ref. 6-3) points out that although significant progress has been made in large-scale weather forecast capability, there are several important gaps when mesoscale models of severe weather are considered. One problem is a lack of basic knowledge of all of the important physical processes that operate on this scale. Although there are many ideas and hunches, it is still unknown as to which processes are essential to the modeling problem and how to efficiently represent the processes in numerical models. (Project SESAME is a beginning to the study of this problem, but implementation and the subsequent analysis of the results are still a few years away.)

The second major problem that exists, assuming sufficient observations, is processing capability. Anther (Ref. 6-3) hypothesizes a situation in which a grid with 20-km spacing between observation points is used. Thus, a 1,000-km $\times$ 1,000-km grid would involve a 50-by-50 horizontal array, which should be examined at 10 levels in the atmosphere, yielding 25,000 model data points. If six variables are defined at each data point, the number of input data parameters is now 150,000. A typical 24-hour forecast with a large-scale model requires approximately 100 successive solutions of each equation at each point, which translates to 15 million solutions. When this is translated to operations/sec, it clearly begins to stress the capability of even the most sophisticated computer.

REFERENCES - SECTION 6

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- 6-3. R. Anthes, "Numerical Prediction of Severe Storms -- Certainty, Possibility, or Dream?", Bulletin, American Meteorological Society, pp. 423-430, April 1976